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Battelle Technical Review

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Effective Forest Inventory

Evaluating the effects of bleaching upon the tensile strength of cotton textiles. The equipment, which is designed to record the exact pull upon cloth at the moment it tears, is used at Battelle in studying the effect of various types of chemicals upon natural and synthetic textile materials.

MEASURING TEXTILE STRENGTH

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BATTELLE TECHNICAL REVIEW

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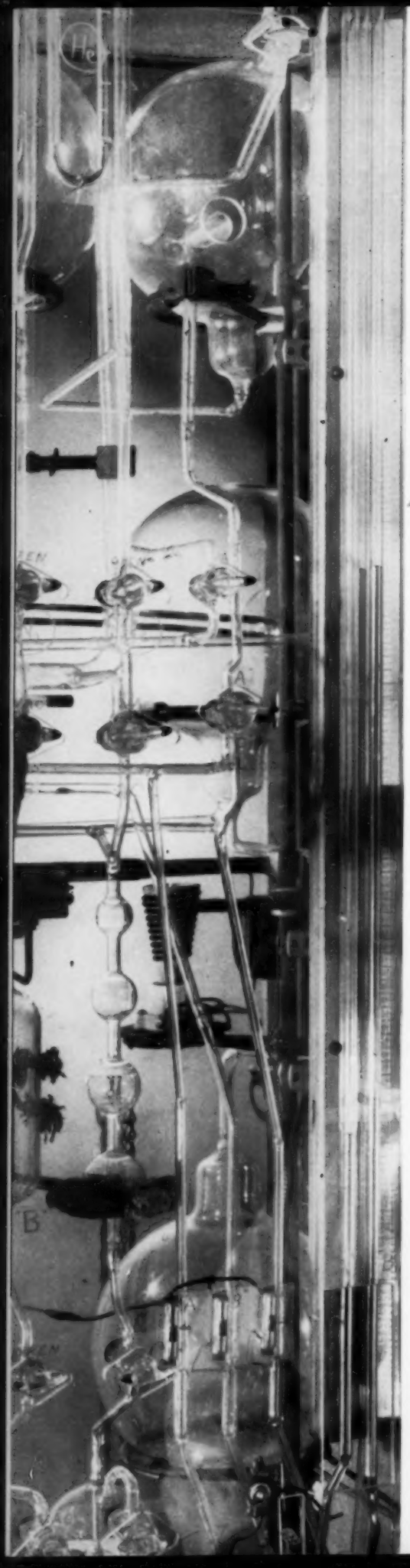

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Communications in Group Research

USUALLY WHEN WE SPEAK OF communications in research, we have in mind the formal type, such as is accomplished through research reports or technical papers. Much has been written about these formal instruments of research communication, and scientists and technologists will always be interested in ways to make them more effective.

But there is another side to communications in research. This is the informal word-of-mouth, written, and expression-conveyed transference of thought that goes on every hour in the research laboratory. Such informal communication is a vital part of team research methodology—and unless it is good, no laboratory can be at its peak in productivity and efficiency.

The elements that make for good internal communications in group research are both tangible and intangible. They include, among other things, the naturalness, sincerity, and completeness research workers show in the casual interchange of thoughts; the lucidity with which our superiors give instructions, using simple terms to "express" rather than "impresss"; the frankness in response we show to the boss; and the willingness we exhibit in keeping him informed about matters that may bear on the course of the work. They also include the informal memos we dash out to keep our coworkers informed; the group meetings we hold to review and plan our work; and the formal memorandums by which we communicate and put essentials "on record".

A friendly smile and a cheery greeting are also important instruments in internal communications; they tell human things that we would never put into a research report. At times, good communications in a cooperative group also means that the research man steps up to reveal special knowledge when that knowledge might be helpful—or even that he utters objection when his experience conscientiously dictates.

Nothing, I believe, is so damaging to group research as regimentation in internal communications. Most modern laboratories try to prevent the paralyzing rigidity that comes with strict procedures for communicating either vertically or horizontally. The only thing that approaches regimentation in its inhibiting effect is personal aloofness, or the attitude of "why bother, it's not my problem". Such aloofness has no place in cooperative research.

A capacity and attitude for easy and natural communications with the group must be ranked along with technical competence as a desirable quality in the research man. And individual success, as well as group success, comes with this quality. Such capacity, however, does not imply verbosity or practiced pomposity. The naturalness and enthusiasm of a simple note saying "It worked!" may tell more than a thousand words—about the project—and about the man who wrote it.

Clyde Williams
President and Director,
Battelle Memorial Institute

VIGNETTE

CONSULTANT TO CHEMICAL INDUSTRIES

HOWARD R. BATCHELDER

The technical demands of many industries and of national defense are a continuing challenge to the chemical industry. Through continuous research, both basic and applied, chemists and chemical engineers are not only meeting the challenge, but opening new fields for developments whose technical and economic impact is still in the future. One of the most potent instruments for advance in these fields, in the opinion of Howard R. Batchelder, is the application of nuclear energy.

As opportunities for relating nuclear to chemical research have increased, Howard's interest in the new field has also expanded. As a consultant in chemical engineering at Battelle, with liaison responsibilities between the Institute and its industrial sponsors, he is able to use his broad background of experience in helping to set up research programs that utilize nuclear facilities.

In recent years, Howard has contributed to research planning involving irradiation studies of petroleum and petrochemicals; the application of nuclear energy to varied chemical and chemical engineering problems; chemical engineering studies of conventional and unusual processes; and the economic evaluation of chemical and chemical engineering developments.

Howard's broad experience has for its foundation an M.S. as well as a B.S. degree in organic chemistry from the Massachusetts Institute of Technology. As a research chemist for Standard Oil Company of Indiana, his work led to patents on improved gasoline and diesel fuels and high pressure processes. Research in the Development Laboratory of the United Gas Improvement Company resulted in patents on processes for the recovery of petroleum by-products. As chief chemical engineer for the Pennsylvania Industrial Chemical Company, Howard directed the design and construction of new chemical installations. His next responsibility was as technical director of research in gaseous fuels for the Institute of Gas Technology. Prior to joining Battelle, Howard served as Chief of the Gasification Planning Section at the Louisiana, Missouri, Synthetic Fuel Plant of the U. S. Bureau of Mines. There he directed studies of coal gasification, including plant operation, purification of synthesis gas, and the economic aspects of synthetic fuels.

The author of more than a score of articles and papers, Howard has 15 patents to his credit. His professional interests include membership in the American Institute of Chemical Engineers, the American Chemical Society, and the American Gas Association.

The Batchelder family has gained a son (by marriage) and has a second daughter in high school. Yet even with his daughters grown, Howard is still seeking time to indulge in his favorite hobbies of hunting and bowling.

Effective Forest Inventory

Continuous Forest Inventory provides forest industries with information for effective operational, policy, and research planning.

by WILLIAM C. FINLEY

MANAGING THE RAW PRODUCTS of the forest has, for a long time, been a matter of serious concern to the forest products industries. Good forest management requires a broad spectrum of information about timber stands covering such matters as their composition, physical condition, growth, change, and reaction to cutting. The timber cruise, as developed in the past, was not designed to provide the kind of detailed data called for by modern inventory methods. Even recurrent cruises may not always yield the factual material needed for the type of inventory control desired by forest industries today.

In their search for improved inventory techniques, some companies interested in forest management turned to sampling techniques. Improvement in inventorying was the result. In recent years, a more advanced system, known as Continuous Forest Inventory, has been receiving attention.

Continuous Forest Inventory, generally known as CFI, has been adopted by a number of companies. It is a systematic sampling process based upon: (1) permanently located sample plots (usually circular); (2) careful and refined measurements of both trees and plots; (3) a carefully planned system of grading trees; (4) the use of a punched-card system for storing and analyzing data; and (5) remeasurements at frequent and regular intervals to establish trends.

The sample plots under CFI, which may range from one-fifth to one-seventh of an acre in size, are located at regular intervals throughout a timber stand. Their locations are determined statistically so as to provide adequate sampling. One forest, comprising 270,000 acres, contains about 750 plots.

One of the first steps in the establishment of a CFI system is the setting up of measuring procedures. These will include such matters as the determination of what measurements are needed both for trees and plots, precisely how the measurements are to be made; and, where estimates are required, the establishment of standard procedures for making them. Greater dependability of data is thereby assured. The care employed in measuring and estimate-making is one of the important factors in the effectiveness of CFI.

Under the system, the individual trees in the sample plots are the basic units for the inventory. All commercial and near-commercial trees are numbered and significant data are recorded for each. Typical information for each tree includes, in addition to diameter breast high (DBH), tree height, species, and plot, such data as: quality grade (lumber, veneer, tie, cordwood, etc.); vigor grade; volume of wood; mortality (from wind, girdling, crowding, insects, diseases, flooding, etc.); growth (approaching merchantable size); and usable length.

On the basis of these data, companies can quickly determine what proportion of the trees should be cut immediately, what may be cut within a period of years, and what may be considered as capital growing stock. At the same time, information on the volume of wood in quality classes ranging from best timber grade to culls is also available.

In addition to a tree-by-tree inventory, CFI also provides for punched-card records on a plot-by-plot basis so that the sample plots can be sorted into groups for administrative, silvicultural, and operational purposes. The types of data recorded for the sample plots may include: district location; ground-cover type (bottomland, pine, oak-maple, upland swamp forest, etc.); condition class; stand density; site productivity; age class of trees; cutting period; silvicultural treatment (thinning, pruning, weeding, protection measures etc.); type of soil; and operability (access to road, water, etc.).

All of these data are recorded on mark-sensing cards which can be filled out by foresters on the spot. Later, the information on the marked cards is transferred to punched cards for use in evaluation steps. All information can then be processed by automatic machine methods which include standard systematic machine and manual checks to insure personal and statistical accuracy. The ability of automatic machines to sort, tabulate, and compute data into any desired combinations provides management with a flexibility of analysis hitherto unheard of in forest inventory procedures. The ease of handling data makes frequent inventories practicable; many companies are finding that inventories at three-year intervals are advisable.

Use of CFI in Research

The value of a CFI program as an aid to practical management is well established. However, research-minded professional foresters, looking for correlations between environmental factors and tree growth and quality, may find CFI an equally valuable research tool. The CFI system, as currently used, provides very complete data on forest composition and growth. Battelle scientists believe that the collection of more precise and detailed data on important plot characteristics should also be included in the inventory, in order to fully exploit its usefulness.

One of the most significant factors influencing tree growth is the soil. While "type of soil" constitutes one entry in the plot record of CFI, scientists will recognize that this notation is not adequate for the complex relationship between soil and forest growth. Such specific characteristics as soil structure and texture, thickness of soil layers, drainage and aeration, soil reaction, fertility, and organic matter content affect both the composition of the forest cover and the quality and rate of growth of the tree crop. Thus, these soil properties should be taken into account in evaluating present timber stands and in planning reforestation programs.

The unique advantage of CFI in this suggested joint management-research effort lies in the ease with which large quantities of complex data may be quickly analyzed and interpreted, using machine processing methods. Detailed information on forest composition and growth, matched by equally complete information on associated soil characteristics, will enable the professional forester to make sounder decisions in the management of present timber resources, in reforestation planning, and in the purchase of new forest lands.

William Finley serves as liaison man between Battelle and the forest-products and wood-using industries. Prior to joining the Institute, he was industry forester and manager of industry forest properties for the American Walnut Manufacturers Association and industry consultant to wood products associations. Earlier he had carried on forestry work and served as assistant manager of forest properties of the University of Michigan, where he received a B.S. degree in science and forestry. Author of several articles on forestry and wood products, he is an active member of the Forest Product Research Society and of the Society of American Foresters.

The principles and techniques of CFI, however, are not limited to forest management. They may be applied successfully to allied fields such as fish and wildlife management. The techniques would be of particular value if applied to the collection and analysis of data in compiling census information for fish and wildlife surveys.

Importance of Data Analysis

Obviously the raw data are of little value to those who need the information. Therefore, an important part of any CFI program is the prompt analysis and interpretation of the results obtained from the machines. The following is a partial list of the types of processed data that the CFI system can provide:

1. Net and gross volume by species.
2. Net and gross volume by species within administrative, silvicultural, and operational subdivisions of the forest.
3. Net and gross volume of growth and mortality by species for all majora-rea subdivisions.
4. Stock and stand tables by diameter class and by species to show the structure of the whole forest and of major subdivisions.
5. Statistics for the construction of curves of height, volume, and basal area for each species for correlation with DBH.
6. Statistical checks of volume, growth, and of area for the whole forest and for major subdivisions.
7. Statistical information on pathological and entomological problems.
8. Statistical information on the hazard and risk quotient of whole forests and separate cover classes.
9. A continuous measure of changes in forest cover.
10. Correlations between environmental factors and growth and yield.

These intent men are checking final tabulations on a Continuous Forest Inventory operation being run in Battelle's computing laboratory. The data for the study, punched in more than 4000 cards, was gathered from the 400 sample plots in the forests of Ohio's Muskingum Watershed Conservancy District. The computing machines, which process cards at the rate of 6000 per hour, gave many answers quickly about the District's approximately 30,000 acres of timberland. Shown about the computer (left to right) are: C. B. Stott of the U. S. Forest Service; James Meteer, Consulting Forester, Wooster, Ohio; Jack Belzer, Battelle computing laboratory; Howard Mendenhall of the Muskingum Watershed Conservancy District; and W. C. Finley.

Once tabulation and analysis of the raw data have made the facts available, the next, and perhaps most important, step is their interpretation. When operational management understands what the facts mean, it will be able to greatly improve the production of its timber stands through more intelligent planning. But the same facts may be of even greater significance to the company when interpreted for top management. Then the information can be used in planning and guiding the company's over-all operation.

It is helpful to compare forest control, as implied by CFI, with inventories that have been practiced for years in successful industrial operations. The standing timber constitutes the raw materials at hand. The growth of trees is analogous to the receipt of materials. The drain on forest products is the consumption.

Finally, the manufacturing demands on the forest correspond to the operating needs of the industrial organization.

CFI and Management

Because of the nature of the raw material problems of the forest industries, it appears that the starting point for much executive planning must be the availability of the forest products. Knowing how much timber may be cut, and when, would certainly play a key part in determining rate of manufacture, sales effort required, and probable income from the operation. The same type of inventory information would help to determine needs for plant, equipment, and personnel.

With the kind of data that can be supplied by CFI, company management is able to plan for the future with some certainty. With facilities for analyzing and interpreting the available facts, it can develop a sound timber cutting program, plan a manufacturing schedule to fit the cutting program, and lay out a sales and marketing plan geared to production plans.

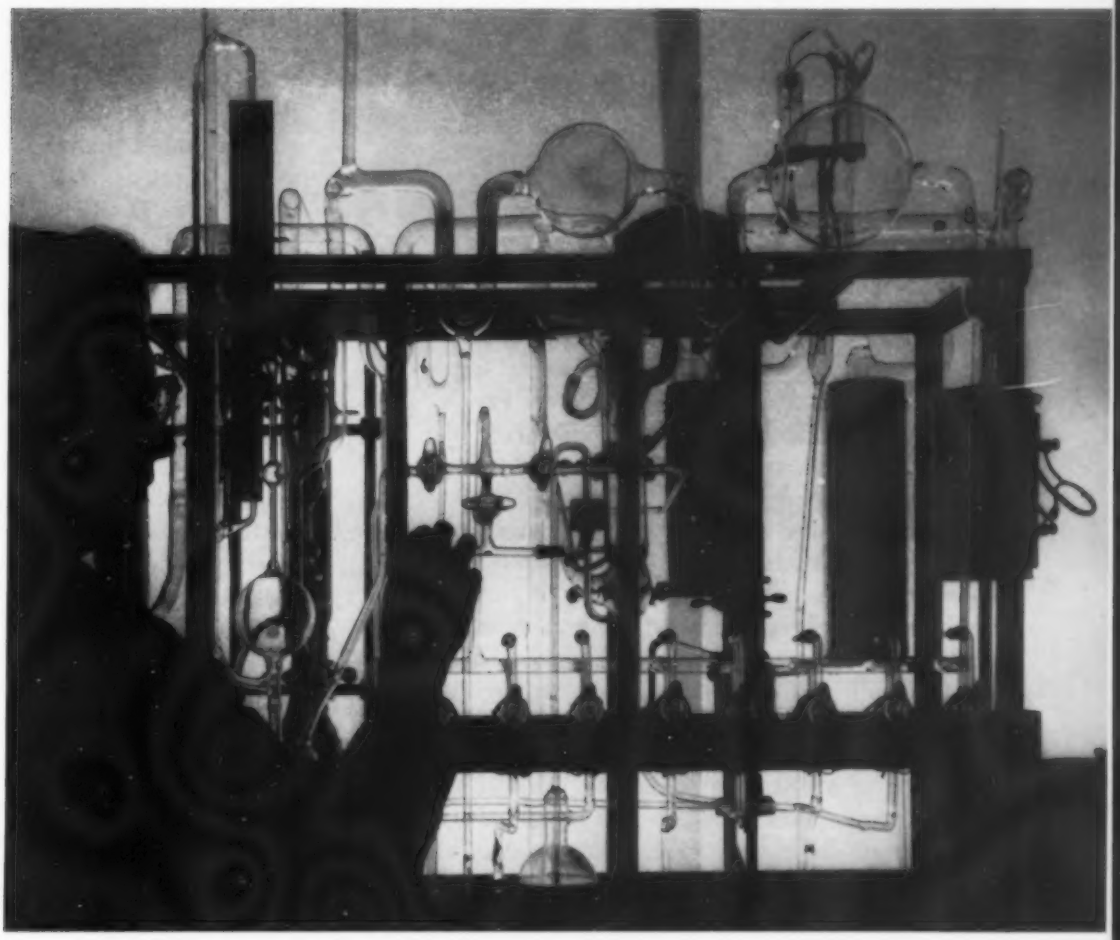
Moreover, CFI can aid management in making decisions on the need for purchasing additional land or forest products. If planned production calls for additional timber, pulpwood, or other products to meet raw material needs, inventory data can be invaluable in determining whether more forest land should be purchased or if the materials should be acquired from outside sources. In plans for future expansion, also, management can decide from CFI data how much additional timber land will be required to meet the needs, what types of land would be most useful, and the rate at which it should be acquired.

Finally, continuous inventory helps to keep the operation in balance, assures maximum timber yields over an extended period, and provides for the most stable and profitable operation for the company over the years.

MARRIAGE WANTED

"Modern electronics has developed into a large body of specialized knowledge regarding precise measuring and control techniques, methods of handling masses of scientific data, and improved techniques of observation. Such knowledge is urgently needed to help in the solution of the exceedingly complex problems of medicine and biology. At present, the life scientist is not in possession of this knowledge. The electronic expert who does possess the knowledge is too unfamiliar with the peculiarities of living substance to make a significant contribution in this field. So far, electronic techniques have been developed for applications of an entirely different character. What is needed at the present time is an intensive cooperative research effort of life scientists and electronic engineers to develop the new field of medical electronics to the point where it can contribute as much to an understanding of life processes and to medicine as electronics contributes today in the field of physical research and industrial practice."

Vladimir Zworykin, Radio Corporation of America
Inventor of the TV tube, in *Saturday Review*



A precision vacuum-fusion apparatus used at Battelle for determining oxygen, hydrogen, and nitrogen in metals. It is capable of determining hydrogen with a precision of one part in 10 million and oxygen and nitrogen of one part per million by weight.

Methods are available now for providing most of the answers to current and future . . .

Problems of Gases in Metals

by Manley W. Mallett

The problem of gases in metals has been with us since man first melted metal. Even the earliest iron founders must have been concerned about the porosity they found in castings. We now know it was caused by the rejection of gases during solidification. This most primitive source of concern about gas-metal relationships is still the only phase of the problem affecting some metals, such as aluminum. The more subtle effects; caused by precipitation of gases, as such, under high aerostatic pressure in microscropic voids in metal or as gas-metal compounds, were not recognized until later.

With each metallic alloy there are problems related to the effects of gas content on the chemical equilibrium of the alloy constituents and on the physical properties of the alloy. The significance of gas concentrations and the determination of means of controlling them are actively being studied for many metals, even those with long metallurgical histories. Thus the effects of gases on the familiar iron alloys and brasses and bronzes still plague us. On the other hand, full realization of the potentialities of the new "wonder metals", titanium, zirconium, and molybdenum requires the meeting of stringent specifications with respect to gas content.

The literature on gases in metals is abundant. Therefore, correlated abstracts or reviews of the subject are timesavers for acquiring background information.

However, most historical condensations contain little critical interpretation of the results quoted. Consequently, the reader must take a Fortean approach and question much of the older data and yet respect it for having pointed the way.

Thomas Graham, as Master of the Mint (London), made the first intensive study of the passage of gases through metals in 1867. His interest apparently was a matter of intellectual curiosity rather than concern with inflation. His studies were made on platinum, palladium, osmium-irdium alloys, copper, gold, silver, and cast steel. He noted that platinum was impervious to oxygen, nitrogen, chlorine, water vapor, CO_2, CO, CH_4, H_2S, and NH_3. He also observed the high permeability of several of the metals for hydrogen and of silver for oxygen.

G. Alleman and C. J. Darlington made a masterly review of the numerous studies on the occlusion of gases in ferrous alloys up to 1918. At this time the methods of analysis for gases in metal were in a state of flux. The literature was full of analyses of samples of gases collected from various iron-carbon alloys and other metals. From the variety and inconsistency of results that had been reported, it was obvious that the reduction of these data to general physico-chemical laws was impossible. However, the seeds were planted, and the next decade was to show our modern methods of gas determination taking form.

The key to understanding the behavior of gases with metals lies primarily in having reliable methods for determining the kinds and amount of gases present. In 1929, von W. Hessenbruch reviewed the methods of gas analysis which had led to the development of the vacuum-fusion method of determining gases in steel by melting the sample in a graphite crucible in vacuum and collecting and analyzing the evolved gases. The method appeared to give quantitative data on the removal of dissolved and combined oxygen, hydrogen, and nitrogen.

For the first time, agreement was found in the results of a number of laboratories which had used the vacuum-fusion method for analyzing steel samples.

J. G. Thompson, H. C. Vacher, and H. A. Bright, in 1936, reported on what appears to be the first extensive "round-robin" program on gas-metal analysis, a cooperative study of methods for the determination of oxygen in steel. Agreement on nitrogen analyses by vacuum fusion and solution distillation methods was also demonstrated. Hydrogen results showed little significance. Wet chemical results for oxygen were reported and the limitations of wet methods discussed.

A paper on the chemistry of steel at 1600 C by J. Chipman (1942) revealed that at this temperature in a steel bath, the common gases include sulfur, phosphorus, zinc, cadmium, magnesium, and calcium as well as the very volatile liquid manganese. He demonstrated the application of the law of mass action and thermodynamic relationships to steelmaking chemistry and presented thermodynamic values for several gas-metal reactions. His subsequent investigations and those of F. D. Richardson and J. H. E. Jeffes have contributed much to our basic knowledge of this subject.

No discussion of gas-metal problems would be complete without mention of hydrogen in metals. The very bulk of the literature is evidence of the seriousness of the hydrogen problem. In regard to hydrogen in steel alone, C. A. Zapffe and C. E. Sims prepared a bibliography of 500 selected references covering the literature to 1939. In 1951, R. W. Buzzard and H. E. Cleaves, performing a similar task, produced a list of about 1200 references. D. P. Smith's book *Hydrogen in Metals* covers much of the literature in regard to metals other than iron.

Present Status of Methods of Analysis

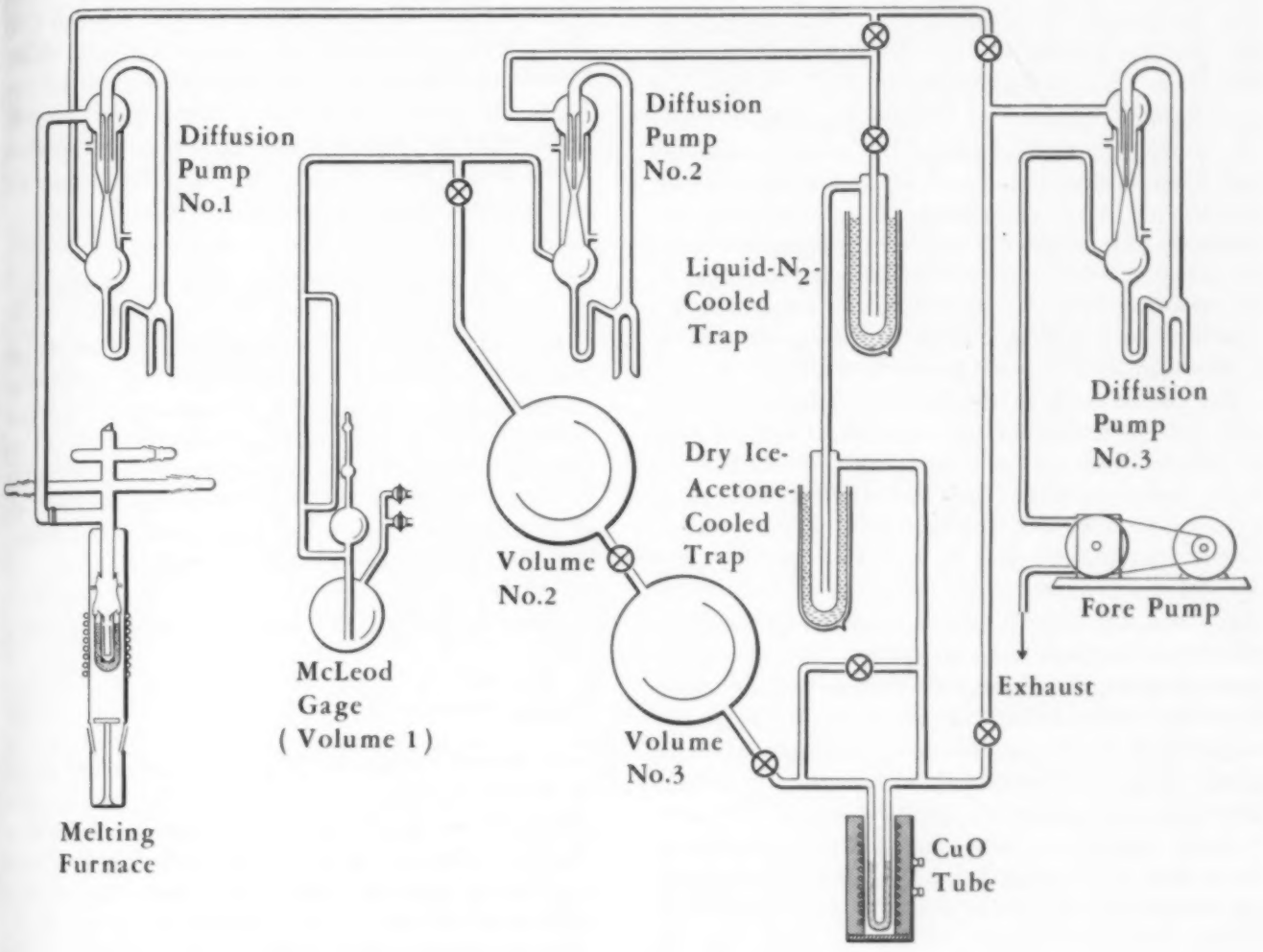
The long period of development of means for quantitatively determining oxygen, hydrogen, and nitrogen in metals has culminated only recently in a group of methods applicable to about all the metals now produced in quantity.

Oxygen

The most universal of the group, is the vacuum-fusion method by which nearly all metals can be analyzed for oxygen and hydrogen and in some cases

The study of gas-metal problems has occupied Manley Mallett since his first association with Battelle. In addition to gas-analysis studies involving many metals, he and his colleagues have developed improved models of vacuum-fusion apparatus and better techniques for determining of hydrogen in various metals. He has also participated in studies of the kinetics of gas-metal reactions, and of the determination of diffusion rates and the solubility limits of gases in metals. In 1947, Mallett was a co-recipient of the American Welding Society's Lincoln Gold Medal for "Arc Atmospheres and Under-Bead Cracking", one of 25 papers of which he has been author or co-author. Prior to joining Battelle, he served as a scientific aide with the National Bureau of Standards and as physicist with the Crucible Steel Company of America.

SCHEMATIC DIAGRAM OF VACUUM - FUSION APPARATUS



for nitrogen. Basically, this method involves melting a metal sample in a graphite crucible in vacuum. Oxygen in solution, or present as a compound, yields carbon monoxide while both hydrogen and nitrogen come off as such. The melting technique varies from metal to metal. For very high melting-point metals, a bath of molten iron is first prepared in the crucible and the sample is dissolved in it.

In the vacuum-fusion method, the evolved gases may be removed from the low-pressure gas collection system and analyzed in a separate gas analyzer such as the Orsat apparatus. However, in most cases the gases are circulated through the low-pressure system by means of a mercury-diffusion pump. During this process the gases pass over hot copper oxide and are converted to carbon dioxide, water vapor, and nitrogen (unaffected) which are then separated and determined by a fractional-freezing method. The final separation of the gases may also be made with dry absorbent chemicals. The vacuum fusion method is so extremely sensitive that as little as one part per million of oxygen or one part per ten million of hydrogen by weight, in a ten-gram metal sample, can be measured.

Numerous other methods have been used for determining oxygen in metals. Most were long and tedious and yielded uncertain results. Designed to dissolve the metal and leave a residue of oxygen compounds, the methods often lost dissolved oxygen as well as the more soluble compounds. The separation of oxygen compounds from other insoluble residue also posed a problem. About the only chemical method used actively today is the bromination method which was developed for titanium and zironium and which currently is being extended to chromium, vanadium, and steels. Although this method reportedly has given good results for some laboratories, it is subject to several sources of error.

Hydrogen

Hydrogen is more easily determined than oxygen. The most satisfactory methods for determination of this gas also involve the use of vacuum techniques. For steels, the vacuum-fusion hydrogen results are incontestable; however, an advantage is gained by use of the tin-bath method where the steel is dissolved under vacuum at 1150 C in a fused silica crucible. Because of the low temperature, blank corrections are negligible. Moreover, the evolved hydrogen is largely undiluted by other gases, thus making it convenient to improve sensitivity of analysis by use of larger samples. The fraction of hydrogen in the evolved gas is quickly determined by a thermal conductivity gage.

For metals such as titanium and zirconium a hot diffusion-extraction method is used in which hydrogen is diffused from the solid metal at 1200 to 1450 C. Since hydrogen is the only gas evolved, analysis is reduced to a simple determination of gas volume. Lower temperatures may be used if extraction times are increased to compensate for slower diffusion rates. Also used are several modifications of the method which are designed to be economical from the standpoint of initial investment. However, an over-all saving is seldom realized, and simplicity of procedure and certainty of result are sacrificed. Methods involving combustion and diffusion into an inert gas stream have also been used with questionable results.

Other metals have been analyzed for hydrogen by the diffusion-extraction method. In each case temperatures and times must be selected that will be compatible with the melting points of the metals and the diffusion rates for hydrogen.

Nitrogen

Although the vacuum-fusion method yields reasonably good nitrogen values for low-alloy steels, considerable uncertainty is introduced by the presence of nitride formers. Extreme cases are the metals titanium and zirconium from which only traces of nitrogen are recovered during quantitative extraction of oxygen. On the other hand, the solution-distillation chemical method for nitrogen is both economical and accurate. The most popular version of the method is the micro-Kjeldahl technique. Formerly, this method gave variable and sometimes incorrect results where insoluble nitrides were present. However, present practices, involving special precautions in the dissolution of residues and careful identification of the absolute insolubles (graphite), insure excellent results.

In general, accurate, precise methods for making several analyses per day per apparatus are now available for investigation of almost any gas-metal problem which may arise.

Many effects of gases in metals, about which a great deal is known, reappear from time to time as problems to new companies and inexperienced metallurgists. Even the more experienced technologists may be troubled by changes in source or raw materials which result in gas problems new to them. Following is a brief review of today's gas-metal problems.

Current Problems of Gases in Ferrous Metals

Ferrous metallurgists presently face several serious gas-metal problems. Included are those of gas-induced embrittlement and porosity of weldments, hydrogen embrittlement of large castings, and disruption of the bond between babbit facings and steel bases of friction bearings. Attracting less attention at the moment, yet of considerable importance, is the problem of blistering of coatings of porcelain enamel, tin plate, and electrodeposited metals. Also of interest are the effects of gases on the ductility and machinability of special steels.

Oxygen

In general, the problem of porosity caused by oxygen in ferrous castings has been solved by use of deoxidizers. However, in the field of welding, porosity induced by the carbon-oxygen reaction is not entirely controlled. Also, the effects of oxygen remaining in solid steel are still not fully understood. In unkilled (not deoxidized) steel, oxides combine with sulfides to form low-melting compounds which cause hot shortness or high-temperature brittleness. This condition is eliminated by deoxidation. On the other hand, in free-cutting steels the use of strong deoxidizers such as aluminum, titanium, or zirconium reduces machinability quite markedly.

One of today's most important problems related to oxygen is that of its surface effects. For example, cast iron tends to be slowly permeable to oxygen. During porcelain enameling, this oxygen accumulated at or near the surface may lead to porosity in the coating.

Nitrogen

The effects of nitrogen in ferrous materials may be attributed primarily to precipitation of a nitride phase. Since precipitation is a gradual affair, the deleterious effects of nitrogen depend on heat treatment and increase with time and slow strain rates. Nitrogen causes brittleness in steel but its effect is apparently influenced by the presence of other elements such as phosphorus.

The effects of nitrogen are not entirely detrimental since it is most potent in increasing the strength of steel. Case hardening by nitriding is, moreover, a very useful process.

Hydrogen

Although much criticism has been leveled at the "overemphasis" on hydrogen's troublesomeness, we see evidences of its undesirable effects wherever we turn. Without a doubt, the control of hydrogen content is the most important gas-metal problem in the steel industry today. Though acid-slag melting causes less hydrogen trouble than the basic-slag methods, no common melting practice produces hydrogen-free metal.

The slow progress in eliminating the hydrogen problems may be attributed to the anomalous behavior of this gas. It is always present in steel and yet it is very fugitive. Until recently few hydrogen analyses of steel were based on proper sampling. Much time and effort was devoted to obtaining values of one to two parts of hydrogen per million of metal for good, bad, and indifferent heats of steel. Hydrogen did its damage and diffused from the steel so that at the time of analysis, all samples had reached a common level. It is now recognized that proper samples can be obtained only at the instant of interest.

High hydrogen contents accentuate or cause four important and fairly common types of defects in ferrous metals. They can cause or increase: (1) porosity in steel during solidification of ingots or castings; (2) flakes and shatter cracks, which sometimes form when heavy-section ferritic steels are being cooled to atmospheric temperatures (3) loss of ductility, even in sound steel, during plastic deformation; and (4) delayed brittle fractures in high-strength steels subjected to comparatively low stresses.

The last of these has caused the aircraft industry much concern. Thus, some steels have broken with a brittle fracture when stressed below their yield strength for a sufficiently long time. It is generally believed that embrittlement of this type results from hydrogen introduced to the steel during electroplating with coatings such as cadmium.

Blistering of coatings on ferrous alloys is another interesting, although unusual, defect caused by hydrogen. Hydrogen in steel can diffuse to regions of lower hydrogen concentrations at reasonable rates but diffuses more slowly or not at all in materials such as tin or babbit. These differences in diffusion rates can cause trouble in parts such as steel bearings covered with babbit. As hydrogen diffuses to the surface of the steel, it deposits in any voids available at the interface between the two metals. As hydrogen continues to deposit in the cavities, high gas pressures develop and push up the babbit to form blisters or even to tear the babbit loose. This situation is aggravated under operating conditions because heat generated in the bearing raises the temperature of the steel, and this increases the diffusion rate for hydrogen.

Current Problems of Gases in Nonferrous Metals

In nonferrous metallurgy the major gas-metal problems of today are those of embrittlement. Oxygen lowers the ductility of metals such as molybdenum and chromium, and hydrogen has a similar effect on zirconium and titanium. Probably the most critical problem is the hydrogen-embrittlement of titanium, since the development of long-range bombers and supersonic fighter planes requires the use of ductile titanium. Thus, the security of the nation depends in part on controlling the gas contents of a metal.

Oxygen

Even traces of oxygen cause embrittlement of molybdenum. An addition of one part per million of oxygen to molybdenum originally containing only two parts per million oxygen may destroy its room temperature ductility. Chromium also is embrittled by oxygen and this effect may be expected for other metals having very low solid solubilities for oxygen. It is generally caused by precipitation of the excess oxygen as a brittle oxide phase between the metal grains. In cases of molybdenum and chromium, the oxygen can be removed by annealing the metals in hydrogen which has no observed detrimental effect on them.

On the other hand, titanium and zirconium have solubilties for several weight per cent of oxygen. A few hundredths of a per cent of oxygen is useful to strengthen and harden these metals. However, several tenths of one per cent of oxygen will render them hard and brittle. Control of oxygen in these materials is obtained by melting and fabricating them under vacuum or pure inert gas atmospheres.

Other highly reactive metals such as uranium alloys actually must be jacketed or incased in less reactive metals such as steel for fabrication by rolling. After working the jacket is cut and stripped away.

Oxygen has important effects on the electrical properties of some metals. For example, high conductivity is obtained in copper by making it oxygen free, while the magnetic permeability of iron is greatly improved by removal of oxygen.

Nitrogen

Many of the statments made for oxygen also apply

to nitrogen in nonferrous metals since, in general, the solubilities of oxygen and nitrogen are similar for the same metal. However, nitrogen is easier to control, since its principal source is air, while oxygen is also present in moisture or as a component of slags and refractories.

Hydrogen

Again, as in the case of ferrous alloys, hydrogen causes the principal gas problems in nonferrous materials. Porosity in castings of copper, nickel, magnesium, and aluminum are all related to hydrogen.

Probably the most urgent hydrogen problem today is that of embrittlement of titanium sheet, fasteners, and engine parts used in aircraft. Titanium can give the saving in weight, always important in aircraft construction, and also can withstand the high-temperature requirements of jet-propelled planes. Present maximum specifications of 150 ppm hydrogen in sheet and 125 ppm in castings is being met in only about ninety per cent of the titanium supplied today. If the specifications are realistic, further effort to control hydrogen in titanium must be taken immediately.

Zirconium suffers loss of ductility from precipitated hydrides in a manner similar to titanium. Unless it is solved, this problem may limit certain applications of this metal.

ELIMINATION OF FUTURE GAS-METAL PROBLEMS

We have come a long way in our understanding of gas-metal problems. In fact, it appears we have completed the circle. Some of the earliest works were studies of the gas content of meteorites and its relation to the composition of the upper atmosphere and interplanetary space. Our next concern, no doubt, will be with the effects of these environments on the structural metals of space stations and interplanetary rockets.

An optimistic view of the future is justified by the existence of analytical methods to help solve most gas-metal problems. Modification of these methods for application to other metals or alloys should be no great chore. The diffusion rates and solubilities of gases in many metals are know and can readily be obtained where the need is indicated. The rates and mechanisms of reaction of gases with metals are less completely known but great progress is also being made in this field.

The days when metal producers tried to wish away gas-metal problems is past, and nearly all progressive producers and many of the metal fabricators have installed or are planning installation of apparatus for gas determination. Soon we should speak more of the control rather than the problems of gases in metals.

FREEDOM FOR SCIENCE

"We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. There are tens of thousands of years in the future. Our responsibility is to do what we can, learn what we can, improve the solutions and pass them on.

It is our responsibility to leave the men of the future a free hand. In the impetuous youth of humanity, we can make grave errors that can stunt our growth for a long time. This we will do if we say we have the answers now, when we are so young and ignorant; if we suppress all discussion, all criticism, saying, 'This is it, boys, man is saved!' and thus doom man for a long time to the chains of authority, confined to the limits of our present imagination. It has been done so many times before.

It is our responsibility as scientists, knowing the great progress and great value of a satisfactory philosophy of ignorance, the great progress that is the fruit of freedom of thought, to proclaim the value of this freedom, to teach how doubt is not to be feared but welcomed and discussed and to defend this freedom as our duty to all coming generations."

R. P. Feynman, Norman Bridge Laboratory of Physics, California Institute of Technology, in *Science*

NOTES from BATTELLE

* SYSTEMS ENGINEERING

People are looking more and more to electronic and mechanical computers and to computer-like machines to make operations more automatic. These devices are being adapted, among other things, to the preparation of payrolls, to the analysis of business information and markets, to weather prediction, to the guidance of missiles and aircraft, and to the control of traffic, as well as to the control of manufacturing processes. The devices, of course, form only a portion of the over-all systems in which they operate. Men, environment, processes, opposing military forces, and many other factors influence the behavior of and are part of systems.

To meet the expanding needs of business, industry, and government for research in the development and design of automatic processing and control systems, Battelle has established a Systems Engineering Division.

According to Joseph J. Stone, the new division, of which he is chief, will analyze, synthesize, and engineer systems to accomplish office and factory automation and the automatic handling of miliary data. It will also undertake research in the fields of information theory, human engineering, machine computation, and systems simulation.

The new division is staffed with specialists in mathematics, human engineering, electronics, computer engineering, and industrial engineering. That staff, in turn, has access to and will team up with Battelle specialists in accounting, economics, manufacturing, management, and those technologies that can contribute to the solution of systems problems. The Institute's digital and analog computers will become working tools of the new division.

In recent years, the electrical engineering, electronics, computer, instrumentation, mechanical engineering, and information-processing groups at Battelle have done much pioneering work in the systems-engineering field. Typical examples of this work are (1) the development of an automatic inventory-control system, (2) the development of a computing facility for use in small arms development, (3) an evaluation of methods for using computing machinery in a large engineering firm, (4) the development of an automatic office, and (5) the development of a statistical weight-control system.

Stone points out: "It is no longer possible to design optimum systems for business offices, factory production, traffic control, navigation, military fire control, and many others by hit-or-miss methods. Modern technological methods must be employed in analysis, design, and development to evolve the best system, and the skills of many technologists must be combined to achieve this goal. Basic knowledge of the necessary functions to be performed by a system must be combined with an understanding of the characteristics and limitations of its component parts and how they function together."

* ARTIFICIAL GRAPHITE

Long used in electrothermic and electrolytic industries, graphite also has unusual high-temperature structural properties. Because of these properties, the material is being studied for possible use in nuclear-power and rocket applications, and the resulting data will enable design engigineers to employ graphite in many cases where high-temperature stability is required. Because of their greater load-bearing capacity, artificial graphites are preferred for many graphite applications.

The physical properties of artificial graphite reflect its unusual structure according to L. D. Loch of Battelle. The material is composed of crystals that consist of two-dimensional layer planes stacked like playing cards in a deck and while bonding within the layers is very strong, bonding between the layers is weak. This makes graphite stable at high temperatures, and yet the easy slippage on planes also makes it a good lubricant. The material does not melt at atmospheric pressures, but sublimes at about 6500 F. Not being resistant to oxidation it must be protected by oxidation-resistant coatings.

The properties of graphite may vary widely even within the same grade. Bend strengths of different grades may vary from 1500 to 4500 psi. Tensile strength is about one-half the bend strength, while crushing strength is about double the bend strength. The material's strength increases with temperature, and at 3000 F it is one of the strongest of materials. With a thermal conductivity approaching metals and

with low thermal expansion and elastic modulus graphite has excellent resistance to thermal shock.

The properties summarized above make artificial graphite highly useful in a number of fields. Thus in metallurgy it is used in dies and molds in many continuous-casting processes. Graphite is excellent for multiple extrusion of aluminum, and it is employed for crucibles and boats in the treatment of many metals, including semiconductor materials.

Graphite has helped to speed the development of rockets. Its properties have made it extremely valuable in combustion chambers and nozzles where it can withstand extreme temperature changes, and when coated, the erosive effects of gases moving at very high velocity. The material is also widely used in the construction of nuclear reactors.

The need for materials with adequate strength at high temperatures is one factor retarding the development of these fields. Artificial graphite can play an important part in breaking this bottleneck.

* NITRIDED FILM RESISTORS

Resistors of small size and great stability are required in many military and aircraft applications. Recent investigations at Battelle have shown that film resistors of either Cr-N or Cr-Ti-N may have certain advantages for such uses since they possess many of the desired properties.

Battelle technologists E. H. Layer and E. R. Olson report that in the one-watt size, such resistors can be made with resistance values in the megohm range with a temperature coefficient of resistance less than 0.01 per cent per degree centigrade. Furthermore, unsealed Cr-N and Cr-Ti-N resistors, operating at full rated load at an ambient temperature of 150 C, exhibit a resistance change of only a few per cent in 1000 hours. In the one-quarter-watt size, resistors with values of several hundred thousand ohms more can be made with properties similar to those stated above.

The study showed that Cr-N resistors show greater potential than Cr-Ti-N from the standpoint of resistance, but the current preparation process lacks the necessary reproducibility. Cr-Ti-N resistors, however, can be made with good reproducibility of properties. The latter can be specified for applications where: resistance values less than 2 megohms in the one-watt size and 250,000 ohms in the one-quarter-watt size are specified; excellent moisture resistance is imperative; a temperature coefficient of resistance of less than 0.015 per cent per degree centigrade (over the range —65 C to 150 C) is needed; and a permanent resistance change of less than a few per cent in 1000 hours can be allowed for full-load operation at an ambient temperature of 150 C.

* COBALT INFORMATION CENTER

Cobalt is almost indispensable in modern alloys and steels operating at high temperature. The increasing demands for jets, turbines, and rockets call for high-temperature creep-resistant materials. Because of its importance as an alloying element in such materials, the future of the lustrous, silver-white metal is assured.

The need for better dissemination of information about research on cobalt and cobalt-containing alloys has led to the establishment of a Cobalt Information Center at Battelle, under the direction of Dr. F. Rolf Morral. The center is to be sponsored by some of the principal cobalt producers.

Cobalt has already shown its potentialities in glass and enamel manufactures, the chemical industries, and in medical and medicinal uses. In the communications field, it is an indispensable alloying element for Alnico magnets, used in bells, telephones, radio, television, radar, and other electronic gear. Cobalt is also used as a binder for sintered carbide for utilization in cutting tools.

Further demand for the metal is expected as the study of the properties of high-purity cobalt and its effects on alloys and steels goes on. A few years back, there was considerable concern because the demand for the metal was greater than the supply. However, technological developments and the construction of new production facilities appear to assure an adequate supply for the future.

The information center will collect available data on the preparation, processing, and uses of cobalt; it will distribute the information to cobalt users upon request. Of particular interest will be the results of the study and evaluation of the above data and of new developments and potentials of the metal.

* Most metal powder particles are produced in highly irregular shapes. In many cases, and for many uses, such shapes are desirable. However, occasions also arise when spherical particles of metals and alloys are required. The need for spherical particles usually presents a problem because few metal powders are produced in such a form. Recent investigations at Battelle have demonstrated the feasibility of producing spherical particles of metals such as stainless steels, titanium, bronzes, aluminum, and molybdenum.